Challenge Driven Education for sustainability in engineering. A White Paper

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Abstract

Two contemporary academic movements can be argued to be important for the integration of more field-practice- and cross disciplinary team-based learning experiences into the engineering education curriculum. Firstly, the growth of research in sustainability challenges in combination with the need for change in engineering education, which is seen to evolve from environmental focus to the inclusion of social and transdisciplinary approaches. Secondly, the evolution of engineering education in general: from traditional and instructive to student centered, constructive and practice oriented as well as from isolated and exclusive to an inter-twined part of society, where society's need for "socially responsible future entrepreneurs, innovators and leaders".

This implies that all engineers need to be equipped with knowledge, skills, values and experiences in order to meet the needs of society.

Challenge driven education (CDE) is an evolving concept that can bridge engineering and sustainability. In the challenge driven education, students are working on real-life and often real-time challenges in society and industry. The students work with open-ended, ill-defined problems that do not have a single right answer. With the challenge driven education approach, the aim is to position ideas, innovations and decision making in the forefront of the learning process.

InnoEnergy is a transnational educational initiative supported by the European Institute of Innovation and Technology (EIT). From the investigation made on the integration of CDE in seven international and cross-border InnoEnergy Masters' programs, the need appeared for a common understanding on CDE within the knowledge innovation community. The investigation aimed to explore: the perceived drivers and barriers for CDE; the different approaches for integrating CDE in the seven masters' programs; and the perceived scope for CDE mapped to the achievement of competences for sustainability.

Preliminary findings showed that there was a common core of successful initiation of the integration of the CDE approach, although differently in the seven masters' programs, from different perceptions of CDE for sustainability within the community. Furthermore, the findings revealed a narrow view of sustainability, where the concept is implicitly integrated or "obviously" in some programs with a intend at finding more sustainable energy solutions.

An InnoEnergy CDE White Paper has been elaborated, setting the goal for the future progress of challenge driven InnoEnergy MSc education. The paper contributes the definition behind this concept and a strategy on the future development, as well as some best practices of the work so far. Furthermore, the overarching

learning outcomes for EIT programs and the UNESCO cross-cutting key competences needed for problem solving for sustainable development, have been merged as new expected outcomes, so that intended learning outcomes based on both perspectives are developed.

1 Introduction

An immediate transformation towards sustainable energy innovations is crucial for our future society. The mission of the Knowledge Innovation Community (KIC) InnoEnergy, consisting of universities, companies and research centers, is to be at the forefront of this development in Europe, through research, innovation and commercialization projects, and education and professional training.

Challenge-driven education (CDE) is a way to catalyse and ensure that education needed for this purpose will be implemented. The definition behind this concept will be explained, and a strategy for the future development will be presented as well as some best practices of the work so far.

Challenge-driven education is an excellent tool for teachers and students that are not only interested in the transmission of knowledge, but also on the development of skills and, going even further, in contributing personally in making possible a positive societal change. In Challenge-Driven education, students work on real-life and often real-time challenges in society and industry.

2 Challenge Driven Education in InnoEnergy

2.1 The motivation for Challenge-Driven education in InnoEnergy MSc programs

Professionals of engineering education step-by-step come to the agreement on the need to equip engineers with knowledge, skills, values and experiences in order to meet the needs of society (Cech, 2014; Declaration of Barcelona, 2004). The former epistemological structures are disrupted and consequently an "epistemic community" gain progressively understanding about new constructed knowledge (Knorr-Cetina 2007; Klein, 2008; Vilsmaier, 2015).

InnoEnergy is a transnational educational initiative, corresponding to one out of the nine knowledge innovation communities (KIC) supported by the European Institute of Innovation and Technology (EIT). The InnoEnergy consortium has the mission to educate professionals ready to take on the challenges of tomorrow (EIT, 2018), offering high standard Master of Science (MSc) programs in different universities, members of the European Higher Education Area (EHEA), which is monitored by the ministers of education in each EU member country.

In this context, European agendas for higher education have to be reflected in the InnoEnergy education programs, where the European Commission decided on "A renewed EU agenda for higher education" in 2017; the "Paris Communiqué"[1] provides a road map for the continued collaboration and progress towards the goals of the Bologna process; and the "Standards and Guidelines for Quality Assurance in European Higher Education Area"2 regulated processes for quality assurance.

[1] The Paris Communiqué, was signed by the European Higher Education Area (EHEA) Ministers in Paris, on May 25th 2018. http://www.ehea.info/Upload/document/ministerial_declarations/EHEAParis2018_Communique_final_952771.pdf

[2] The "Standards and Guidelines for Quality Assurance in European Higher Education Area" were authored by the European Association for Quality Assurance in Higher Education, together with the European University Association (EUA), the European Students' Union (ESU) and the European Association of Institutions in Higher Education (EURASHE). https://enqa.eu/index.php/home/esg/

The requirement arises for a lifelong learning skills training, through a student-centered and cross-organizational education, where all institutional and disciplinary; physical and virtual; and research and teaching borders should be crossed.

In alignment, the EIT MSc programs emphasizes the integration of innovative learning-by-doing curriculum in the courses, also providing student mobility on a cross-organizational an international level. Their Overarching Learning Outcomes (OLOs) are aiming at competencies for sustainability, entrepreneurship, creativity, innovation, research, intellectual transformation as well as leadership and the assessment of students' learning aim to measure competence- and impact-based activities "in a real-life situation to create a change or solve a challenge" (EIT, 2018:19).

On the other hand, the Sustainable Development Goals (UNESCO, 2017) sets the goal for the UNESCO strategy for Education for sustainable development, where InnoEnergy as an innovation community within the EIT has an opportunity to step forward in innovative energy engineering education.

Within this framework the InnoEnergy program directors at each program undertake from 2015 the integration of CDE project-based courses in the MSc programs, in a valuable effort to introduce to the greatest extent, challenges that should be socio-technical and relate to the UN SDGs, especially the SDG7 "Sustainable energy", since it is the priority area for InnoEnergy. Involved faculty was commited in general to offer strong and motivating learning experiences. The interest for harmonize and go together making further progress to the implementation of Challenge-Driven approaches within the InnoEnergy MSc programs, leads to the elaboration of a White Paper on CDE in InnoEnergy, as a result of a two years research (2018-2019) research.

3 Methodology

3.1 First phase. State of the Challenge-Driven education in InnoEnergy MSc programs

In the first phase, the research team started out semi structured interviews with academic program directors and faculty running the project courses, were transcribed and analyzed, based on their CDE integration. Furthermore, a selection of the students' final reports was analyzed from three of the seven programs, SELECT, RENE and SENSE.

The results and conclusions of the work were validated at the InnoEnergy Teachers Conference (TC) (April 2018, Santa Cruz de Tenerife), where a Co-creative workshop was held. Around 40 teachers, program coordinators and InnoEnergy team members from the seven MSc discussed and reflected in a World Café format, upon four different themes based on the information collected, namely: Definition of CDE; CDE implementation; External stakeholders' roles; Link to SDGs.

3.2 Second phase. White Paper on Challenge-Driven education in InnoEnergy

Starting the second phase of the research, the conclusions of the TC resulted on the core of a proposal for developing a White Paper for Challenge Driven Education in the InnoEnergy community. At this point, in order to fully understand CDE in the InnoEnergy programs, it was necessary to collect the considerations of the different actors involved.

In order to explore the relation with stakeholders, the research team examined the InnoEnergy Master's School standardized annual evaluation survey, which is part of the Quality Assurance System (QAS), carried out among second year students, to monitor the quality indicators and take corrective actions when needed. The survey was also analyzed in term of the programs academic content taught at different universities, the relation with the InnoEnergy community and whether the Overall Learning Outcomes were

being adequately addressed, where those considered specifically relevant from the CDE perspective were picked out.

In order to get students' perspective, a focus group was conducted with group of students gathered at the year one in the SELECT MSc, where CDE had been largely implemented, and students asked whether they would like to be followed on a "long-term" basis. Students, both male and female, participated from different nationalities, backgrounds and ages.

Additionally, and with the aim to be aligned with the overall movement of European education, the InnoEnergy Program Directors panel decided the CDE research team to carry out a policy analysis on European, national and institutional level, with the aim to understand how policies and agendas for higher education reflected the ideals of CDE which is aimed to be submitted to a peer-reviewed journal.

Ending the year, on October 2019, two events took place in Brussels in relation to CDE. InnoEnergy was the organizer of the Cross-KIC Education Conference focused on CDE, with the aim of offering a communication platform for contributing ideas and learning and synergies along the different KICs. The CDE research team participated the design of a dynamic educational day (Pecha Kucha session, Fishbowl discussion, keynotes, etc.), aligned with the active format of challenge-based education.

Finally, the CDE research team organized the 2019 Teachers Conference (TC) to become a networking forum, with working spaces for discussion of common current themes and trends about the master programs, facilitating there the introduction of the UNESCO cross-cutting competences (UNESCO, 2017) for the accomplishment of the UN Sustainable Development Goals.

4 Results

4.1 Challenge-driven education as it is described by the InnoEnergy community

Challenge driven education (CDE) is an evolving concept, and one of many alternatives which can bridge engineering and sustainability, also aligned with the previously mentioned agendas for higher education (Högfeldt, 2019). The concept comes from several roots and foundations, as is the integration of practice and theory, with the aim to increase its usefulness and relevance in the engineering professional life (Magnell, 2019; Crawley et al., 2014). The emphasis is also in crossing borders between the university and the society to create more civic, multicultural and outreaching institutions capable to understand and be useful for the society (Högfeldt, 2018; Garibay, 2015).

The wide perspective of CDE is a driver for creating a positive societal change with different perspectives:

- Contributing to the sustainable development goals
- Contributing to societal challenges created in national, regional or city based ecosystems, as well as global
- Contributing to creating a positive socio-economic impact by means of the collaboration with industry, as stated by the EIT

In the CDE, students are working on real-life and often real-time challenges in society and industry, dealing with open-ended, ill-defined, complex, socio-technical problems (Mulder, 2017) that do not have a single right answer. With the challenge driven education approach, the aim is to position ideas, innovations and decision making in the forefront of the learning, including transdisciplinary activities through stakeholder involvement (Tejedor et al., 2018).

The challenge-based learning experience is typically multidisciplinary, takes place in an international context and aims to find a collaboratively identify, analyze and develop or transition to a solution, which is

environmentally, socially and economically sustainable (Malmqvist et al, 2015:4). The CDE activities are often described as an advanced form of project- and problem-based learning (Hoidn & Kärkkäinen, 2014), where the societal focus (rather than just production focus) adds complexity to the problems setting a valuable area for training the cross-cutting competencies of InnoEnergy programs (Kricsfalusy et al., 2018; Chen & Yang, 2019).

4.2 The scenario of Challenge-Driven Education in InnoEnergy MSc programs

The state of the integration of Challenge-Driven education in seven international and cross-border InnoEnergy MSc programs has been analyzed during 2018-2019, aimed to explore the perceived drivers and barriers for CDE; the different approaches for integrating CDE in the seven masters' programs; and the perceived scope for CDE mapped to the achievement of competences for sustainability, as well as the faculty and student perceptions (Högfeldt et al., 2019).

Preliminary findings in the research within the InnoEnergy MSc programs identified several good practices among all programs, consisting in complex and motivating learning opportunities, involving external stakeholders and committed program directors and teachers. Furthermore, the findings revealed a narrow view of sustainability, where the concept is implicitly integrated or "obviously" in some programs with a intend at finding more sustainable energy solutions. Moreover, the InnoEnergy community agreed that the continuous development of the challenge-driven approach in all MSc education programs should target processes for enhancing sustainable energy engineering education and leading the path to transition. The findings from interviewing InnoEnergy program directors and teachers reveal that three of the most crucial aspects for this continuous development are:

a) a shared understanding of the challenge-driven approach within the knowledge innovation community
b) faculty development initiatives which target practical aspects of challenge-driven education and
c) examples on project topics, stakeholders and results which are shared within the community.

4.3 The White Paper on CDE in InnoEnegy

In order to respond to the identified need for a shared understanding, a White Paper was elaborated with the aim to set the goal for the future progress of challenge driven InnoEnergy MSc education, with regards to how Challenge-Driven education is described by the InnoEnergy community and how the EIT Overarching Learning Outcomes are mapped with the Cross-Cutting Key Competencies (Table 1).

The white paper contributes to the concept definition, a strategy on the future development, and introduces some implemented best practices. Furthermore, the overarching learning outcomes (OLOs) for EIT programs and the UNESCO cross-cutting key competences needed for problem solving for sustainable development, were merged as new expected outcomes, so that intended learning outcomes based on both perspectives were developed. Finally, examples of CDE from the InnoEnergy programs are shared to highlight different challenge-driven education approaches implemented so far by the Innoenergy education community.

Table 1: Overarching Learning Outcomes for Challenge-driven InnoEnergy programs. EIT OLOs mapped with SDGs Cross-cutting Key Competencies.

Nr	OLO's corresponding area	Intended learning outcome
1	Anticipatory competence for a sustainable society	The ability to create visions for the future of energy technologies, transitions, storages and systems and to identify, understand and evaluate the short- and long-term future consequences of plans and decisions from an integrated scientific, ethical and intergenerational perspective and to merge this into a solution-focused approach, moving towards the access to affordable, reliable, sustainable and modern energy for all.
2	Innovation, Entrepreneurship and Strategic competency	The ability to collectively develop knowledge, ideas and technology through implementation of innovative actions to create new or significantly improved products, services, processes, policies, new business models or jobs into feasible business solutions that further sustainability.
3	Systems thinking and creativity	The ability to recognize and understand relationships; to analyze complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty. The ability to think beyond boundaries and systematically explore and generate new ideas.
4	Collaboration competency and Leadership	The abilities to work in cross-disciplinary teams and contexts, to learn from others; to understand and respect the needs, perspectives and actions of others. The ability of decision-making and leadership to deal with conflicts in a group; and to facilitate collaborative and participatory problem solving.
5	Intellectual transforming, critical thinking and Research skills	The ability to transform practical experiences into research problems and challenges, and the ability to use cutting-edge research methods, processes and techniques towards new venture creation and growth.
6	Value judgements and normative competency	The abilities to understand and reflect on the norms and values that underlie people's actions in relation to energy; and to negotiate values, principles, goals and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions.
7	Self-awareness and lifelong learning	The ability to reflect on one's own knowledge, skills and abilities as well as one's role in society; to continually motivate and evaluate oneself in the way of taking actions and continuously developing.
8	Integrated problem-solving competency	The overarching ability to apply different problem-solving frameworks to complex sustainable energy problems and develop viable, inclusive and equitable solution options that promote the access to affordable, reliable, sustainable and modern energy for all, integrating the above-mentioned skills and competences.

5 Conclusions

Challenge-Driven education fits well as teaching and learning methodology with the intentions and aspirations in the InnoEnergy MSc education and on the overall EIT level. Challenges in CDE go further the traditional settings, and even project-based learning, since it is to say that they start before and finalise

later, since they come from a societal need and necessarily generate an impact. Indeed, the CDE goals and design are aligned with strategies for higher education at European level.

Moreover, the InnoEnergy community's academic staff and students, as well as involved stakeholders have been satisfied and motivated with the useful collaboration, resulting from challenge-based education. Participants students, teachers and societal and industry actors valued the opportunity to contribute personally to solutions promoting the SDGs, while developing Anticipatory competence for a sustainable society; Innovation, Entrepreneurship and Strategic competency; Systems thinking and creativity; Collaboration competency and Leadership; Intellectual transforming, Critical thinking and Research skills; Value judgements and Normative competency; Self-awareness and Lifelong leaning as well as Integrated problem-solving competency.

The different InnoEnergy programs have been working on critical energy challenges on various levels, which can be tackled from the challenge-driven approach for InnoEnergy to lead innovations for sustainable energy. Since the CDE concept and experiences continuous gaining knowledge, all programs will continuously need to nurture and develop the CDE. In this sense, the interest is that programs will be verified to include the SDGs learning outcomes and cross-cutting competences (UNESCO, 2017).

Parallelly, the InnoEnergy community acknowledge that higher education success depends mainly on its faculty, staff and students. Therefor the intention raised to support the ongoing successful development of CDE within InnoEnergy through faculty training and through the establishment of a CDE network to promote a shared understanding of the Challenge-driven approach, the sharing of successful experiences within and externally, as well as the advancements of CDE. Finally, the academics perceived ultimately the students to be the drivers for change.

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